Introduction to Software Testing
Chapter 8.5
Logic Coverage for FSMs

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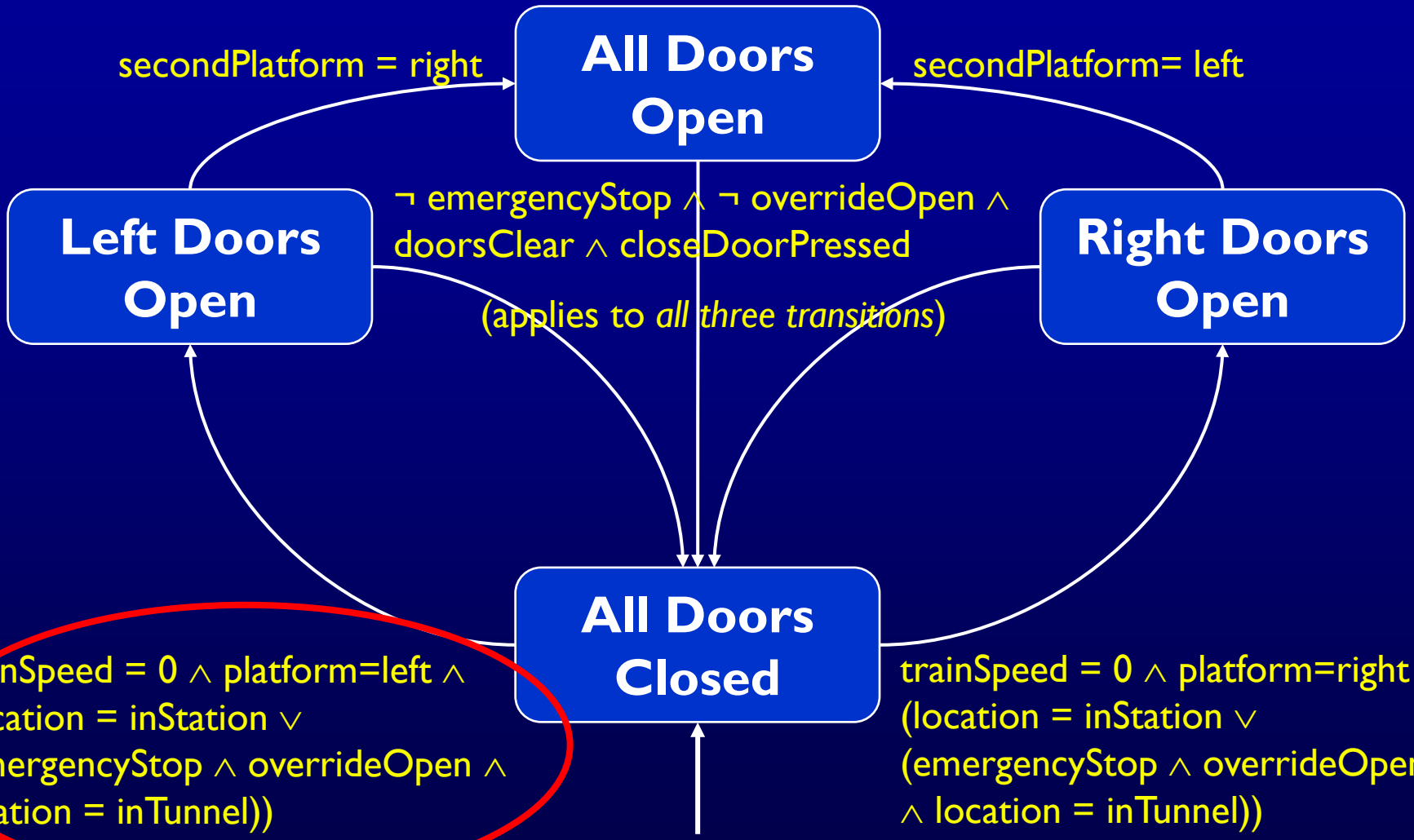
Covering Finite State Machines

- FSMs are graphs
  - Nodes represent state
  - Edges represent transitions among states
- Transitions often have logical expressions as guards or triggers
- As we said :

Find a *logical expression* and cover it

Example—Subway Train


All Doors Open
secondPlatform = right
secondPlatform= left
Left Doors Open
Right Doors Open
¬ emergencyStop ∧ ¬ overrideOpen ∧ doorsClear ∧ closeDoorPressed
(applies to all three transitions)
All Doors Closed
trainSpeed = 0 ∧ platform=left ∧ (location = inStation ∨ (emergencyStop ∧ overrideOpen ∧ location = inTunnel))
trainSpeed = 0 ∧ platform=right ∧ (location = inStation ∨ (emergencyStop ∧ overrideOpen ∧ location = inTunnel))

Determination of the Predicate

trainSpeed = 0 ∧ platform=left ∧ (location = inStation ∨ (emergencyStop ∧ overrideOpen ∧ location = inTunnel))

$P_{trainSpeed = 0}$: platform = left ∧ (location = inStation ∨ (emergencyStop ∧ overrideOpen ∧ location = inTunnel))

$P_{platform = left}$: trainSpeed = 0 ∧ (location = inStation ∨ (emergencyStop ∧ overrideOpen ∧ location = inTunnel))

$P_{location = inStation}$: trainSpeed = 0 ∧ platform = left ∧ (¬ emergencyStop ∨ ¬ overrideOpen ∨ ¬ location = inTunnel)

$P_{emergencyStop}$: trainSpeed = 0 ∧ platform = left ∧ (¬ location = inStation ∧ overrideOpen ∧ location = inTunnel)

$P_{overrideOpen}$: trainSpeed = 0 ∧ platform = left ∧ (¬ location = inStation ∧ emergencyStop ∧ location = inTunnel)

$P_{location = inTunnel}$: trainSpeed = 0 ∧ platform = left ∧ (¬ location = inStation ∧ emergencyStop ∧ overrideOpen)

Test Truth Assignments (CACC)

trainSpeed = 0 ∧ platform=left ∧ (location = inStation ∨ (emergencyStop ∧ overrideOpen ∧ location = inTunnel))

Major Clause	Speed=0	platform=left	inStation	emergStop	overrideOpen	inTunnel
trainSpeed = 0	**T**	t	t	t	t	t
trainSpeed != 0	**F**	t	t	t	t	t
platform = left	t	**T**	t	t	t	t
platform != left	t	**F**	t	t	t	t
inStation	t	t	**T**	f	f	f
¬ inStation	t	t	**F**	f	f	f
emergencyStop	t	t	f	**T**	t	t
¬ emergStop	t	t	f	**F**	t	t
overrideOpen	t	t	f	t	**T**	t
¬ overrideOpen	t	t	f	t	**F**	t
inTunnel	t	t	f	t	t	**T**
¬ inTunnel	t	t	f	t	t	**F**

One of these must be true

One of these must be false

Problem With a Predicate?

	trainSpeed=0	platform=left	inStation	emergencyStop	overrideOpen	inTunnel
inStation	t	t	**T**	f	f	f
¬ inStation	t	t	**F**	f	f	f

The model only includes two locations for the train, *inStation* and *inTunnel*.

So these cannot both be false!

If the train is not in the station (*location != inStation*), then it must be in a tunnel (*location = inTunnel*)!

Possible solutions :

1. Check with the developer for mistakes (do this first)
2. Rewrite the predicate to eliminate dependencies (if possible)
3. Change truth assignment : t t F f f t

Generalize Dependent Clauses

Clauses that depend on each other must have correlated values

That is, inStation and inTunnel must have different values for all tests

Major Clause	Speed=0	platform=left	inStation	emergStop	overrideOpen	inTunnel
trainSpeed = 0	**T**	t	t	t	t	~~t~~ **f**
trainSpeed != 0	**F**	t	t	t	t	~~t~~ **f**
platform = left	t	**T**	t	t	t	~~t~~ **f**
platform != left	t	**F**	t	t	t	~~t~~ **tf**
inStation	t	t	**T**	f	f	f
¬ inStation	t	t	**F**	f	f	~~f~~ **t**
emergencyStop	t	t	f	**T**	t	t
¬ emergStop	t	t	f	**F**	t	t
overrideOpen	t	t	f	t	**T**	t
¬ overrideOpen	t	t	f	t	**F**	t
inTunnel	t	t	f	t	t	**T**
¬ inTunnel	t	t	f	t	t	**F**

We can't implement this test !

Early Identification is a Win!

The process of modeling software artifacts for test design can help us find defects in the artifacts

This is a very powerful side-effect of the model-driven test design process

Expected Results

Expected outputs are read from the FSM :

- When the major clause is true, the transition is taken
- When false, the transition is not taken

	Expected Results
trainSpeed = 0	Left Doors Open
trainSpeed != 0	All Doors Closed
platform = left	Left Doors Open
platform != left	All Doors Closed
inStation	Left Doors Open
¬ inStation	All Doors Closed
emergencyStop	Left Doors Open
¬ emergencyStop	All Doors Closed
overrideOpen	Left Doors Open
¬ overrideOpen	All Doors Closed
inTunnel	Left Doors Open
¬ inTunnel	All Doors Closed

If *platform !=left*, then *platform* must equal ***right***

So the expected output of this test is to go to state "**Right Doors Open**"

Accidental transitions must be recognized when designing expected results during test automation

Summary: Complicating Issues

- Some buttons must be pressed simultaneously to have effect – so timing must be tested
- Reachability : The tests must reach the state where the transition starts (the prefix)
- Exit : Some tests must continue executing to an end state
- Expected output : The expected output is the state that the transition reaches for true values, or same state for false values
- Accidental transitions : Sometimes a false value for one transition happens to be a true value for another
  - The alternate expected output must be recognized

Summary: Test Automation Issues

- Mapping problem : The names used in the FSMs may not match the names in the program
- Examples
  - *platform* = *left* requires the train to go to a specific station
  - *trainspeed* = *0* probably requires the brake to be applied multiple times
- The solution to this is implementation-specific
  - Sometimes a direct name-to-name mapping can be found
  - Sometimes more complicated actions must be taken to assign the appropriate values
  - Simulation : Directly inserting value assignments into the middle of the program
- This is an issue of controllability

Summary FSM Logic Testing

- FSMs are widely used at all levels of abstraction
- Many ways to express FSMs
  - Statecharts, tables, Z, decision tables, Petri nets, …
- Predicates are usually explicitly included on the transitions
  - Guards
  - Actions
  - Often represent safety constraints
- FSMs are often used in embedded software